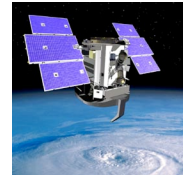


CloudSat Status Report

June 2019

CloudSat Project Manager
Deborah Vane



CloudSat celebrated 13 years on orbit on 28 April!

The spacecraft is healthy and is operating nominally in DO-Op

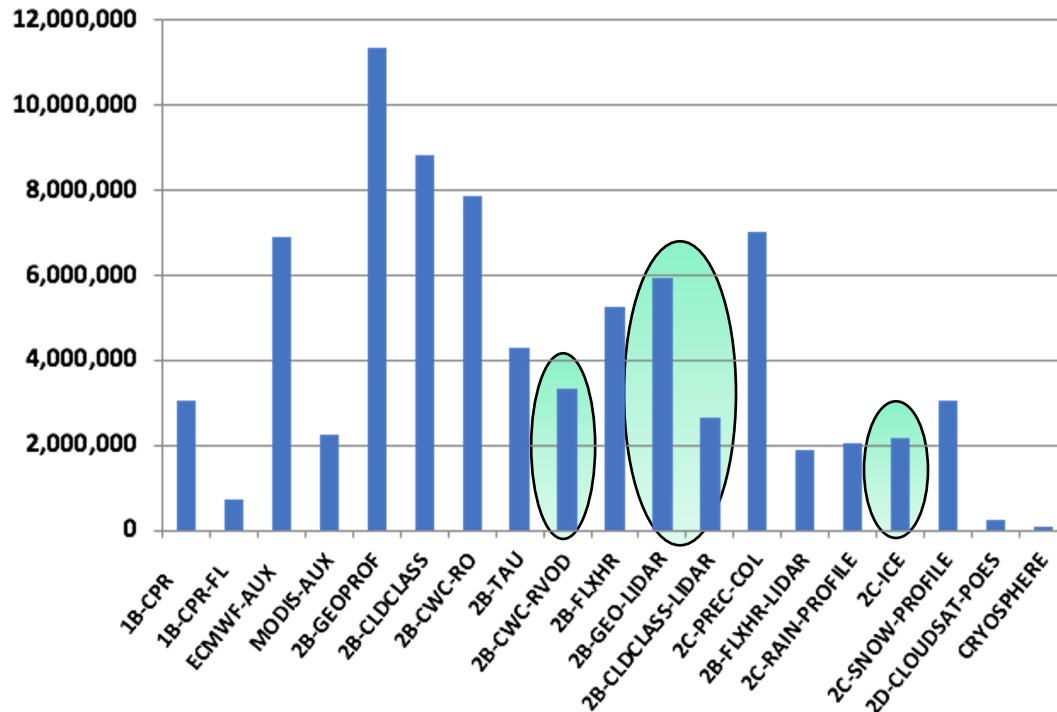
- Daylight Only Operations (DO-Op) continue successfully.
- June 2017 Reaction Wheel #1 failure triggered A-Train Exit in February 2018.
- CloudSat and CALIPSO re-joined formation below the A-Train in October 2018 (the C-Train).
- The CloudSat team developed a reliable, no-reaction-wheel capability to execute orbit burns in the event of another reaction wheel failure.
- CPR is fully redundant; CPR transmit power is better than -25dBZ (-24dBZ is the trigger to switch to the redundant EIK/HVPS), with very gradual loss ~0.5 dB/year.
- Fuel is sufficient for several more years.
- Gentle charging techniques have improved the health of the s/c battery.
- CPR stability-heater action drives NH-Summer minimum battery voltage; a study is underway to modify DO-Op to increase solar heating of s/c cold side (Hip-Hop mode).

C-Train Formation under the A-Train

- Flying ~45 sec behind CALIPSO

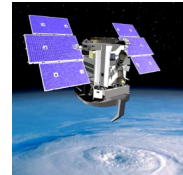
Over 2700 peer-reviewed publications (many shared with CALIPSO)

Data distribution: R04 mission-to-date



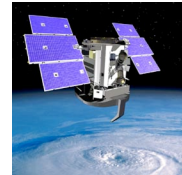
- R05 Joint radar/lidar data products released:

2B-GEOPROF-LIDAR.P1_R05
2B-CLDCLASS-LIDAR.P1_R05
2C-ICE.P1_R05
OCO2CLD-LIDAR-AUX.P_R05
2B-CWC-RVOD.P1_R05

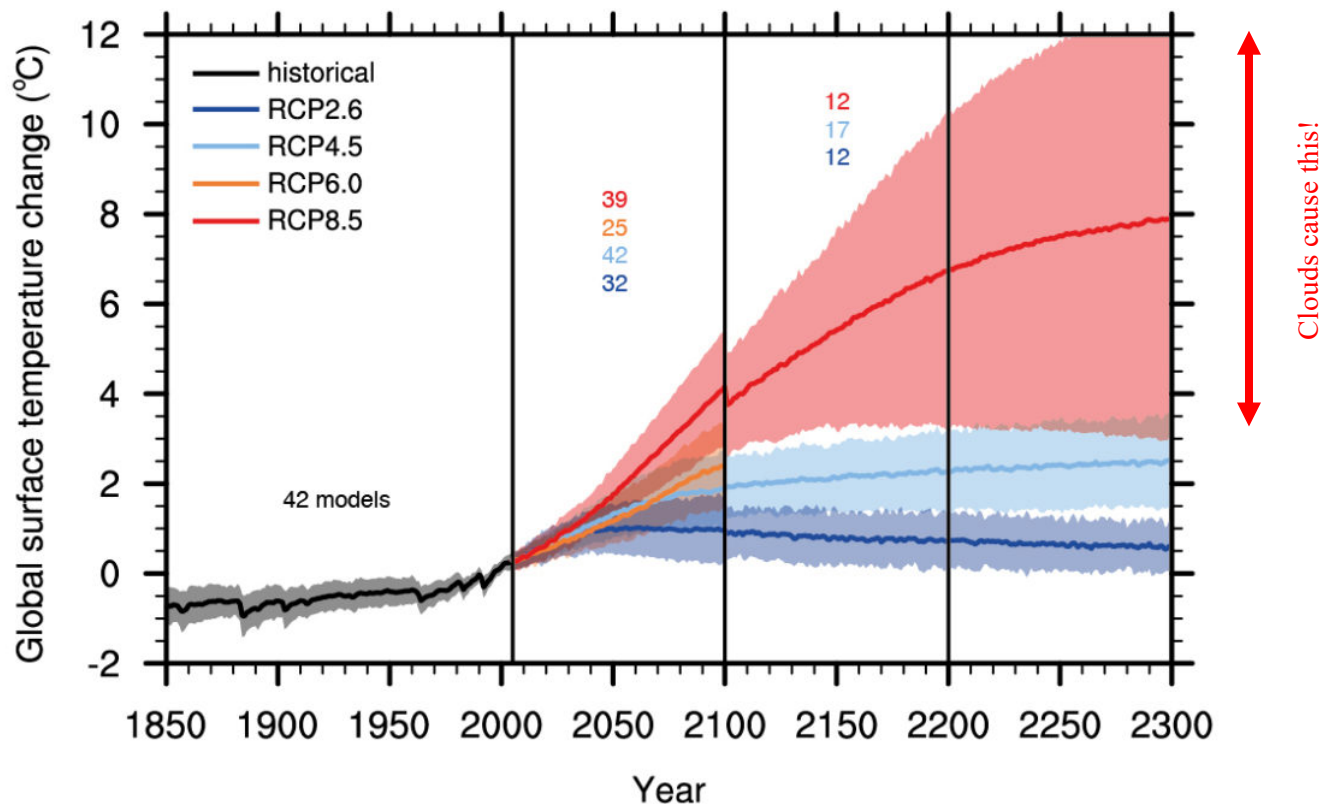


- The last NASA Senior Review recognized the importance of the climate data record begun by CloudSat and CALIPSO.
 - The current data record is 12+ years
 - Future spaceborne cloud radar and lidar are planned for ESA/JAXA EarthCARE mission (launch ~2022 + 3 year mission)
 - The recent decadal survey recommended a Cloud/Convection/Precipitation (ACCP) Mission which is likely to include a cloud radar and lidar (launch ~2026)
- There is an opportunity to stitch together a multi-decadal data record from these cloud radar+lidar data sets.
- When might we detect climate trends in this data?

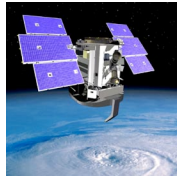
The response of clouds causes
uncertainty in speed and magnitude
of surface temperature change



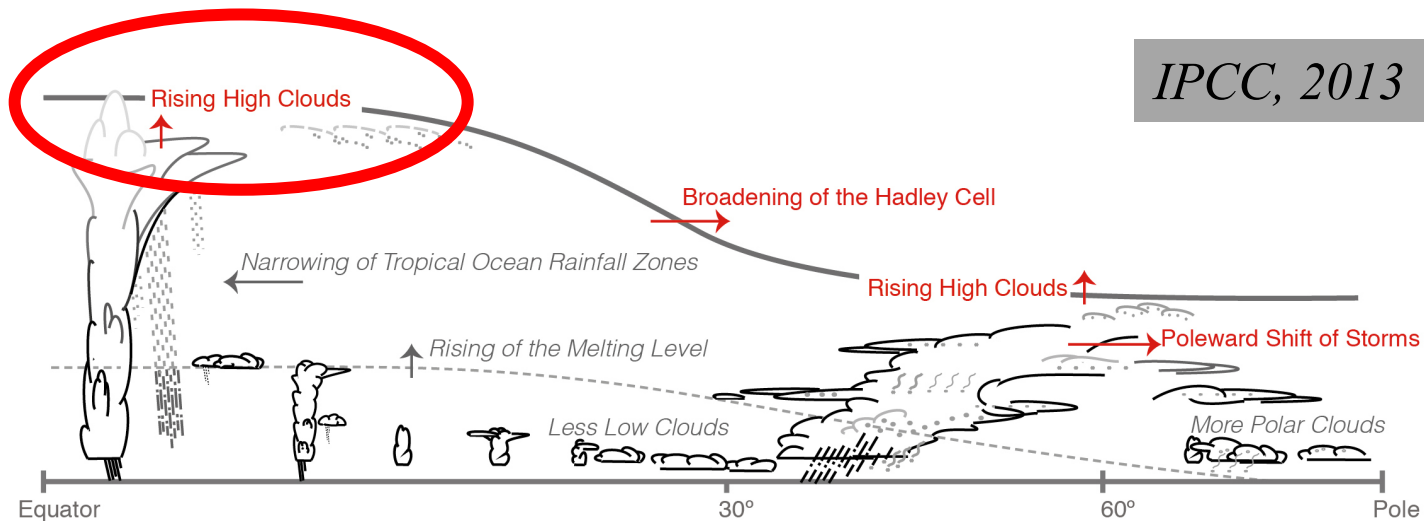
We know that climate will warm....but the response of clouds causes uncertainty in our projections of how fast.



Changes in high cloud are robustly predicted by climate models



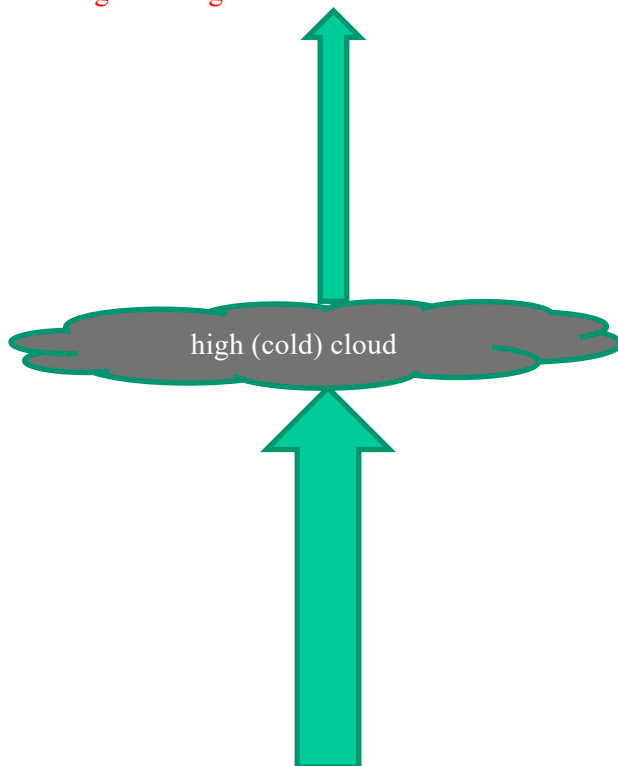
- The height of clouds could provide a feedback on warming through long-wave emission to space.
- Models predict a positive feedback





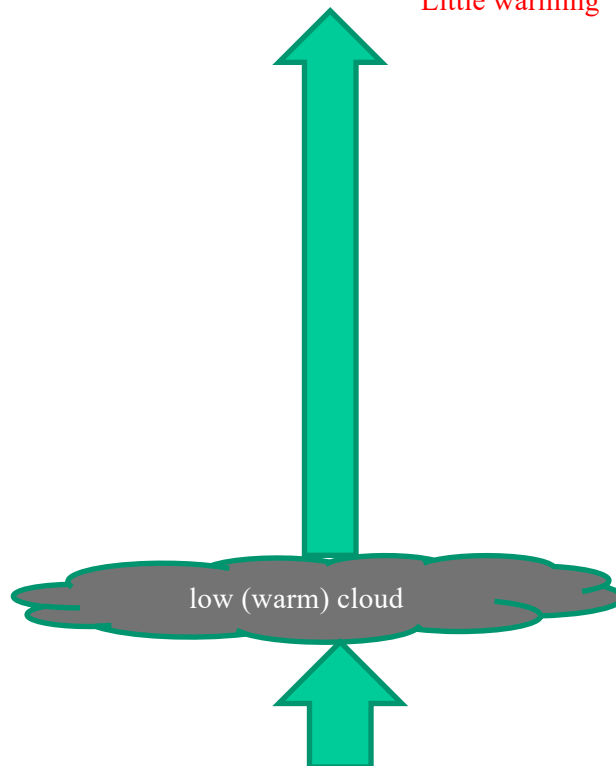
Less upward longwave radiation

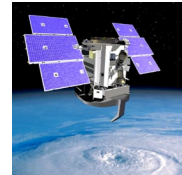
Big warming



More upward longwave radiation

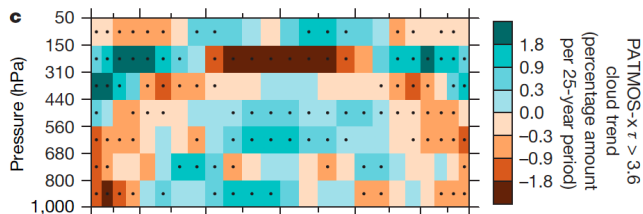
Little warming



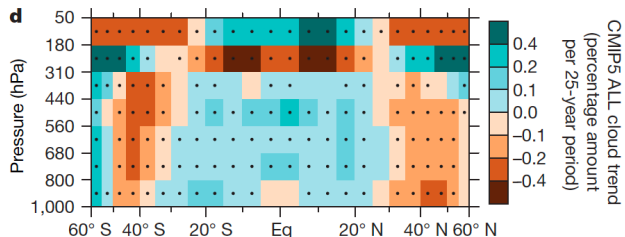


- There is some (*controversial*) evidence that upward shifts in cloud have been detected using weather satellites
 - CloudSat + CALIPSO are establishing a definitive Climate Data Record of these trends

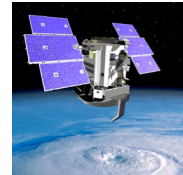
Observations



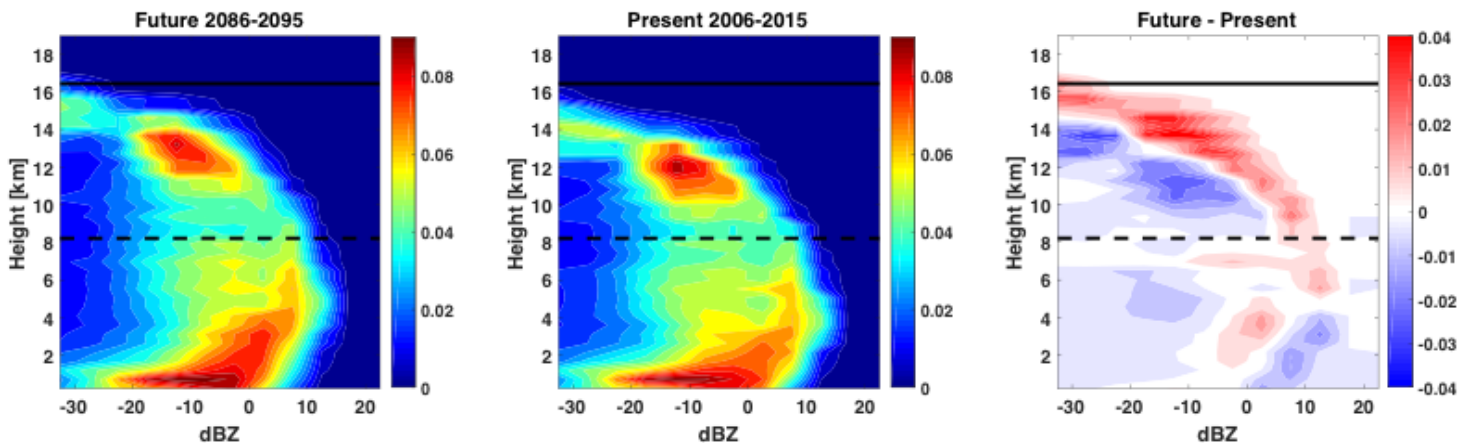
Models

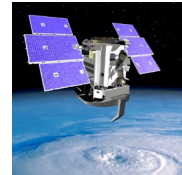


Norris et al., 2016: Nature

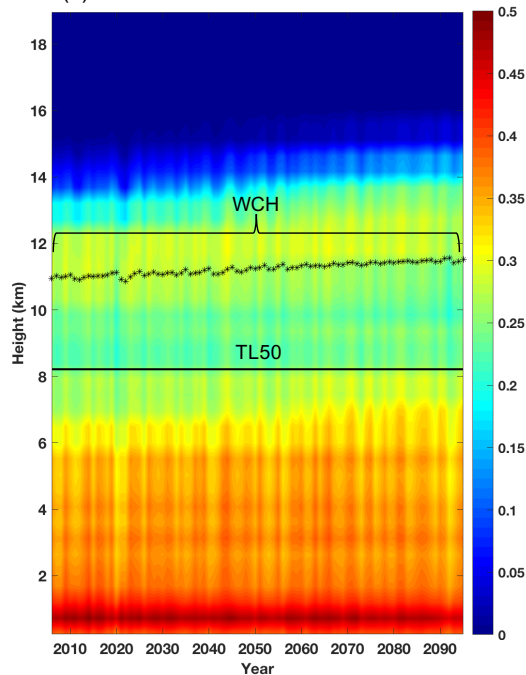


- We've used one climate model to estimate when the climate data record begun by CloudSat will detect upward shifts in cloud heights.
- Model assumes business as usual emissions.
- Clear upward shift in clouds seen in this model

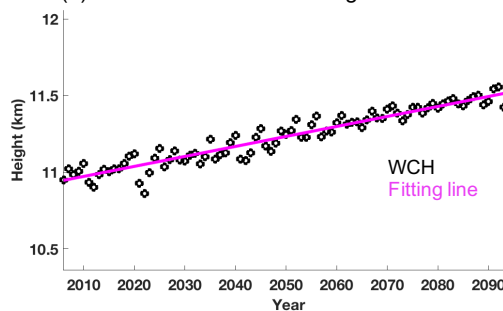




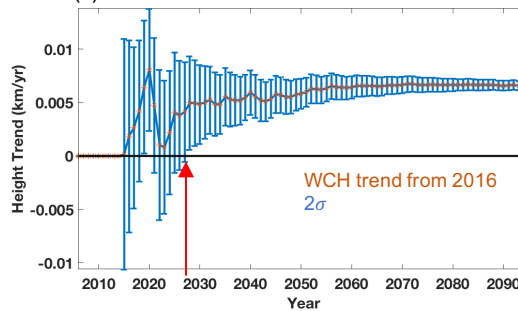
(a) CESM1 CFAD fraction



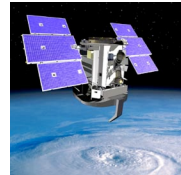
(b) CESM1 WCH with a fitting line



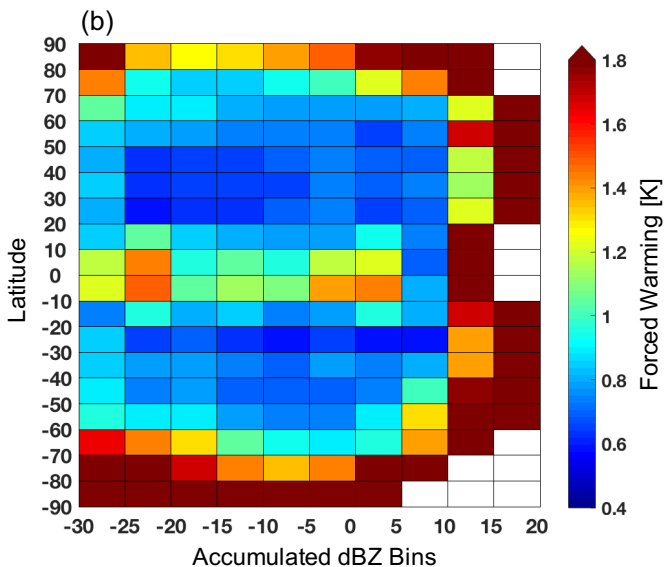
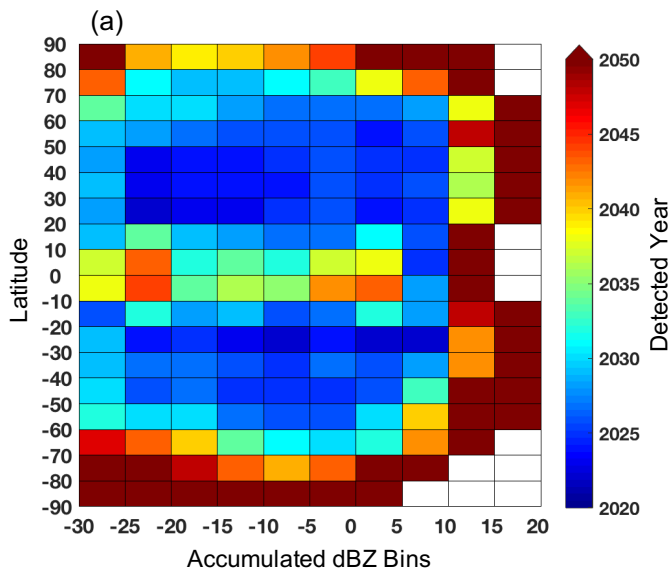
(c) CESM1 WCH trends with standard errors

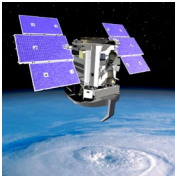


- Method finds trends that are statistically significant and stable
- Method uses averaging to detect trends smaller than the intrinsic range resolution of CloudSat

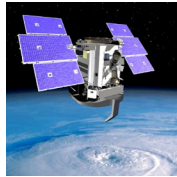


Significant and stable rising clouds detected in some locations by the mid 2020s.





- Rising cloud heights are a positive feedback on climate.
- The signal is large and if warming continues unabated it is likely that we will detect unambiguous trends of the feedback by the mid 2020s in the cloud radar+lidar record. It's really important to extend the record.



CloudSat will propose again at the next call for NASA mission extensions – known as the NASA Senior Review Process:

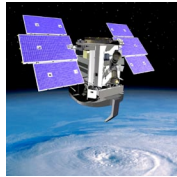
- Expect the "call" for proposals to be received in December 2019
- Proposal will be due the first week of March 2020

CloudSat could operate through 2023. The likely suspects for ending the mission are:

- Reaction wheels – the remaining 3 reaction wheels are getting old, but there is no increased friction observed to-date.
- Battery capacity -- Hip-Hop, when implemented, will increase the minimum voltage, and gentle charging has improved battery performance.

Backup

Operations History (Since the last REVEX)



Reconfiguration Review with NASA HQ: 25 July 2018

- Approval granted for C-Train Mission with CALIPSO

C-Train Formation

- Required numerous maneuvers
- CloudSat / CALIPSO were in formation by October 2018!
- Formation Flying Maneuvers now consist almost entirely of orbit lower maneuvers (with an Inclination adjustment in May 2019).

Inclination Increase Maneuvers: Stop MLTAN Drift

- 23 Oct: Inclination Increase Mnvr #1
- 25 Oct: Inclination Increase Mnvr # 2 & 3
- 30 Oct: Inclination Increase Mnvr # 4 & 5
- 1 Nov: Inclination Increase Mnvr #6

Maneuver History – Planned Maneuvers

- 4 Orbit Raises
- 3 Orbit Lowers
- 6 Inclination Increases - 2 pairs + 2 single burns

Maneuver History – Un-planned Maneuvers

- 2 COLA Maneuvers (1 raise / 1 lower)